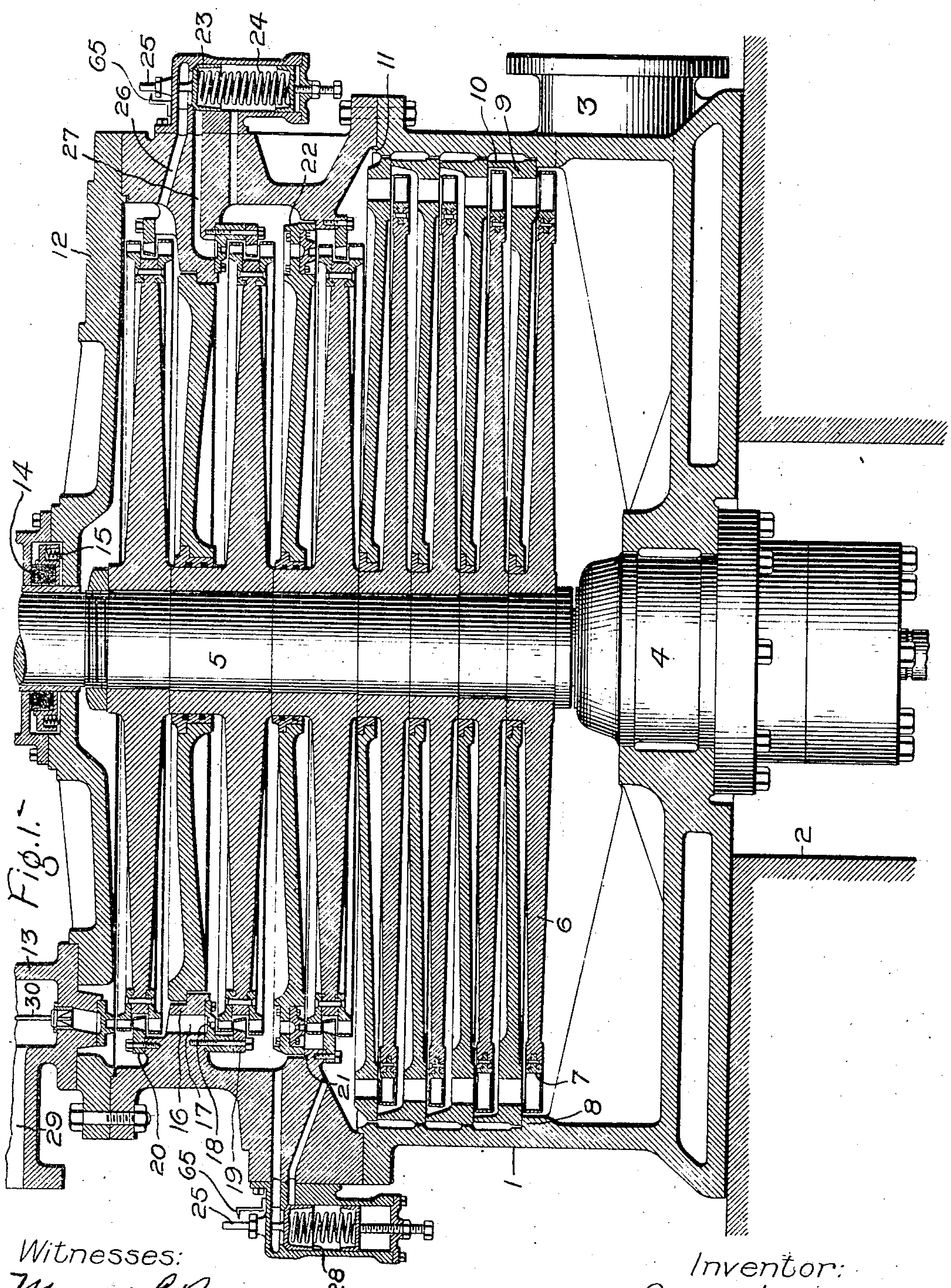
No. 830,900. PATENTED SEPT. 11, 1906.

O. JUNGGREN.

ELASTIC FLUID TURBINE.

APPLICATION FILED FEB. 25, 1905.

6 SHEETS—SHEET 1.



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6 SHEETS—SHEET 2.

Fig. 2.

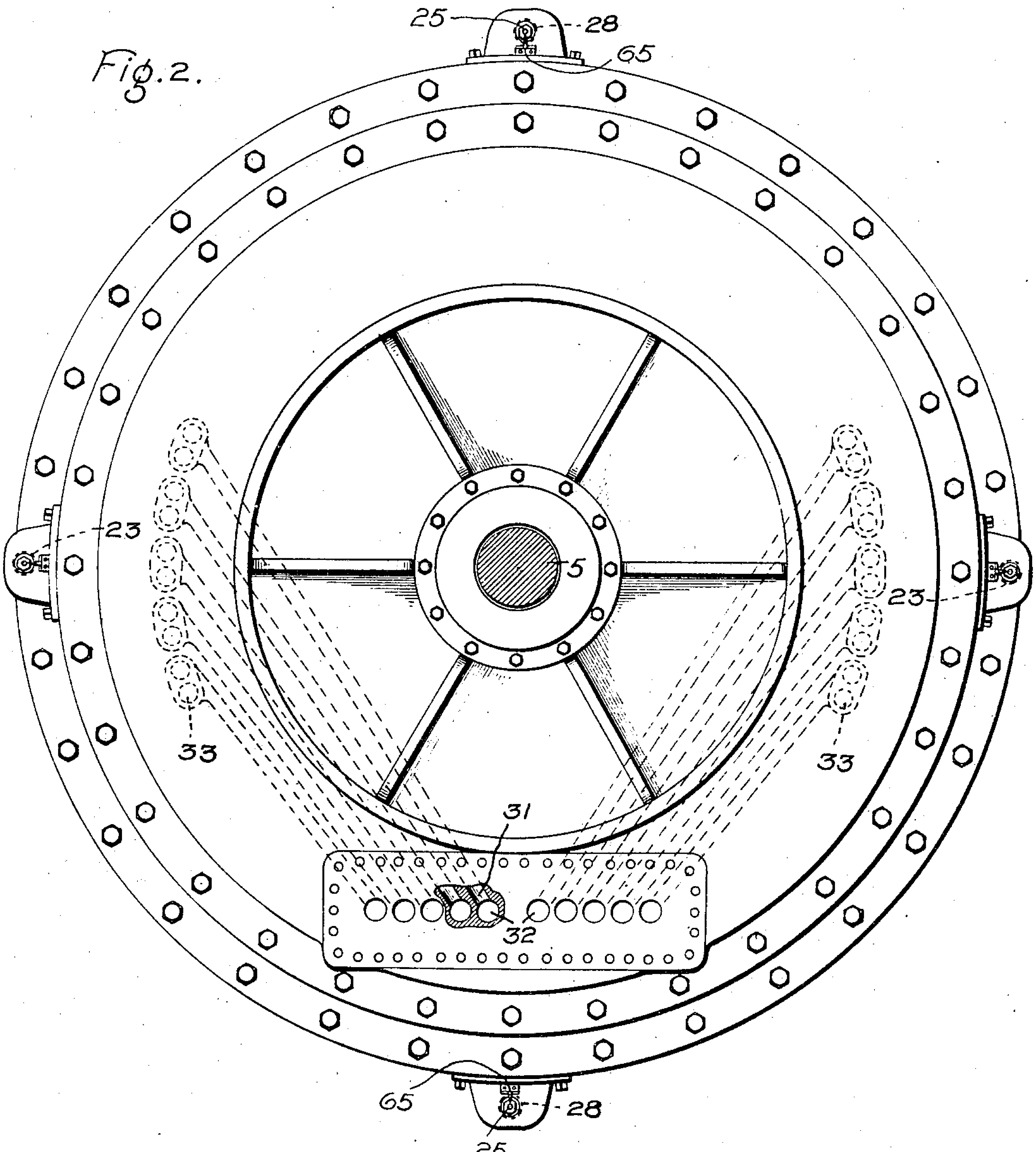
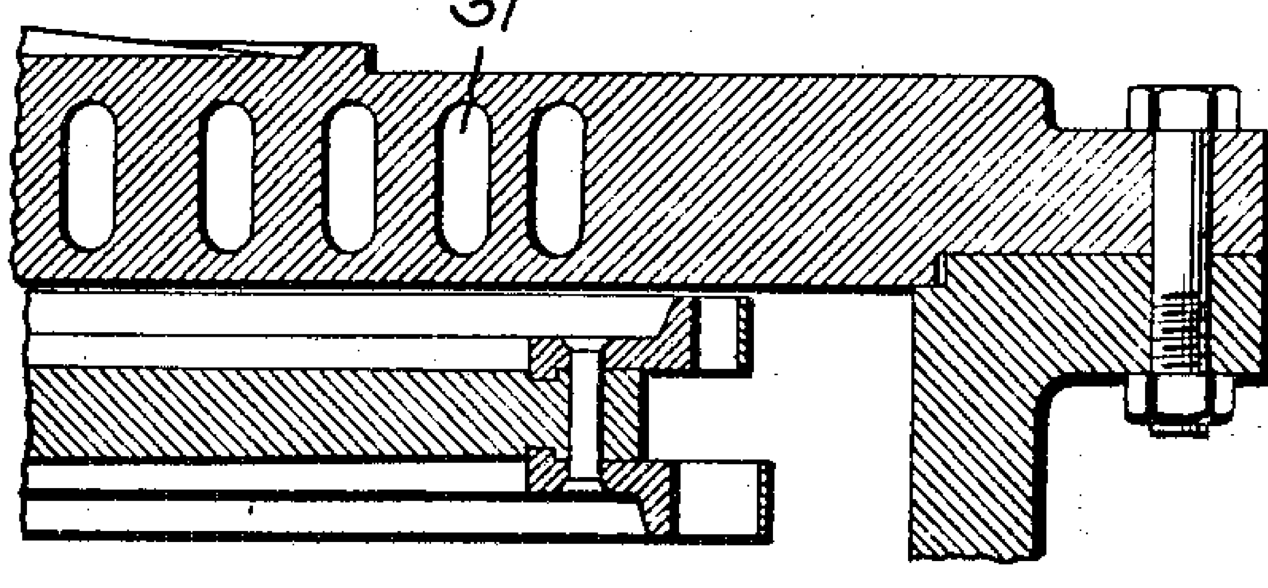


Fig. 3.



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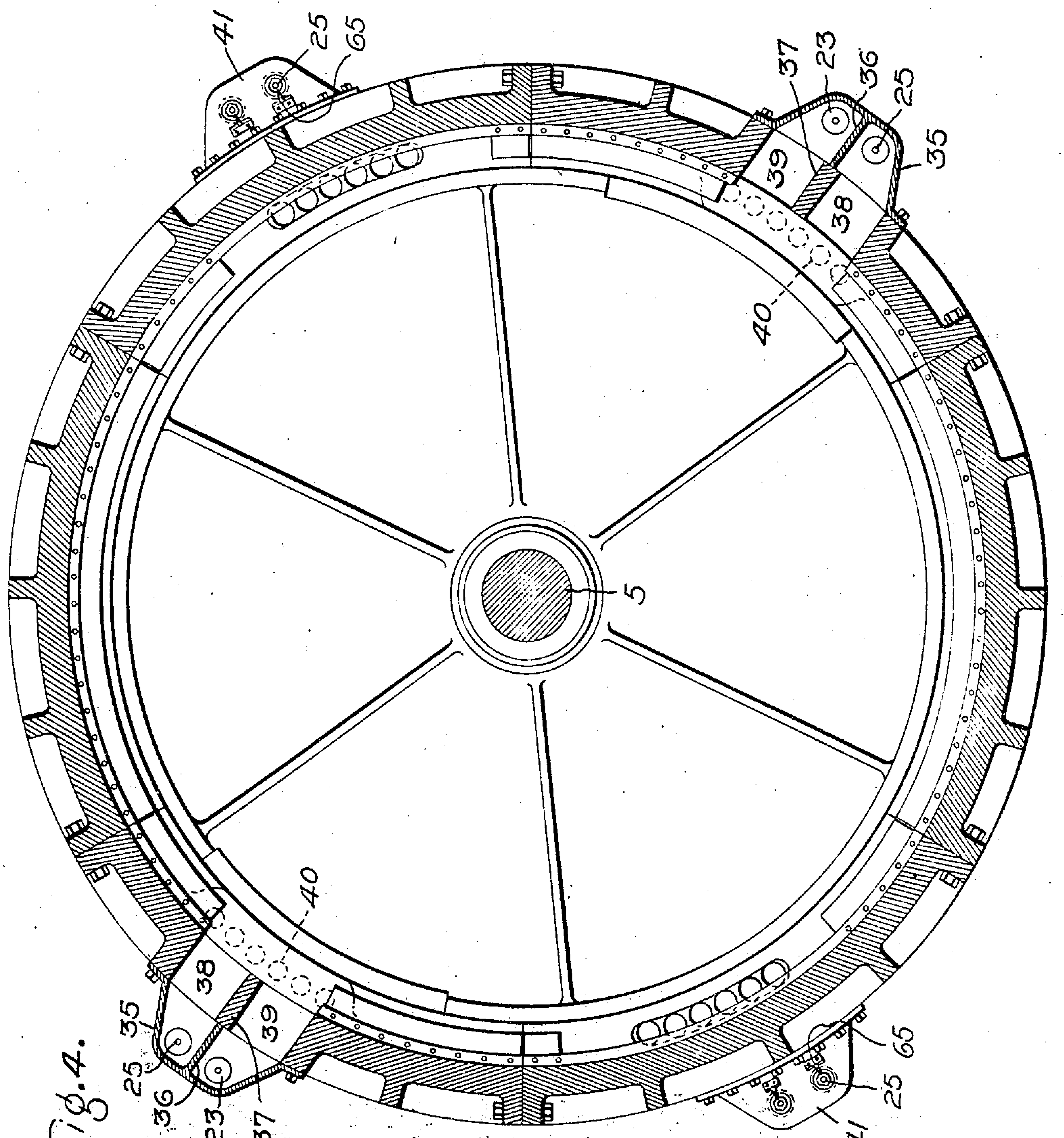

Fig. 4.

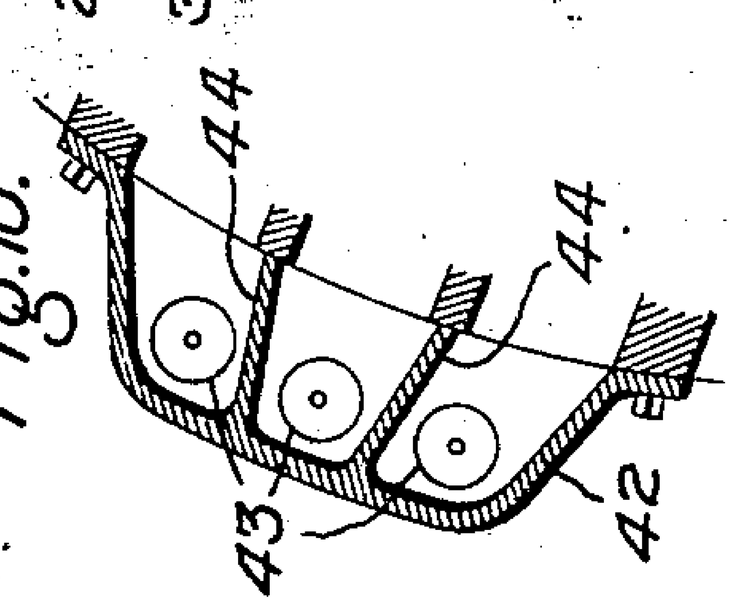

Fig. 10.

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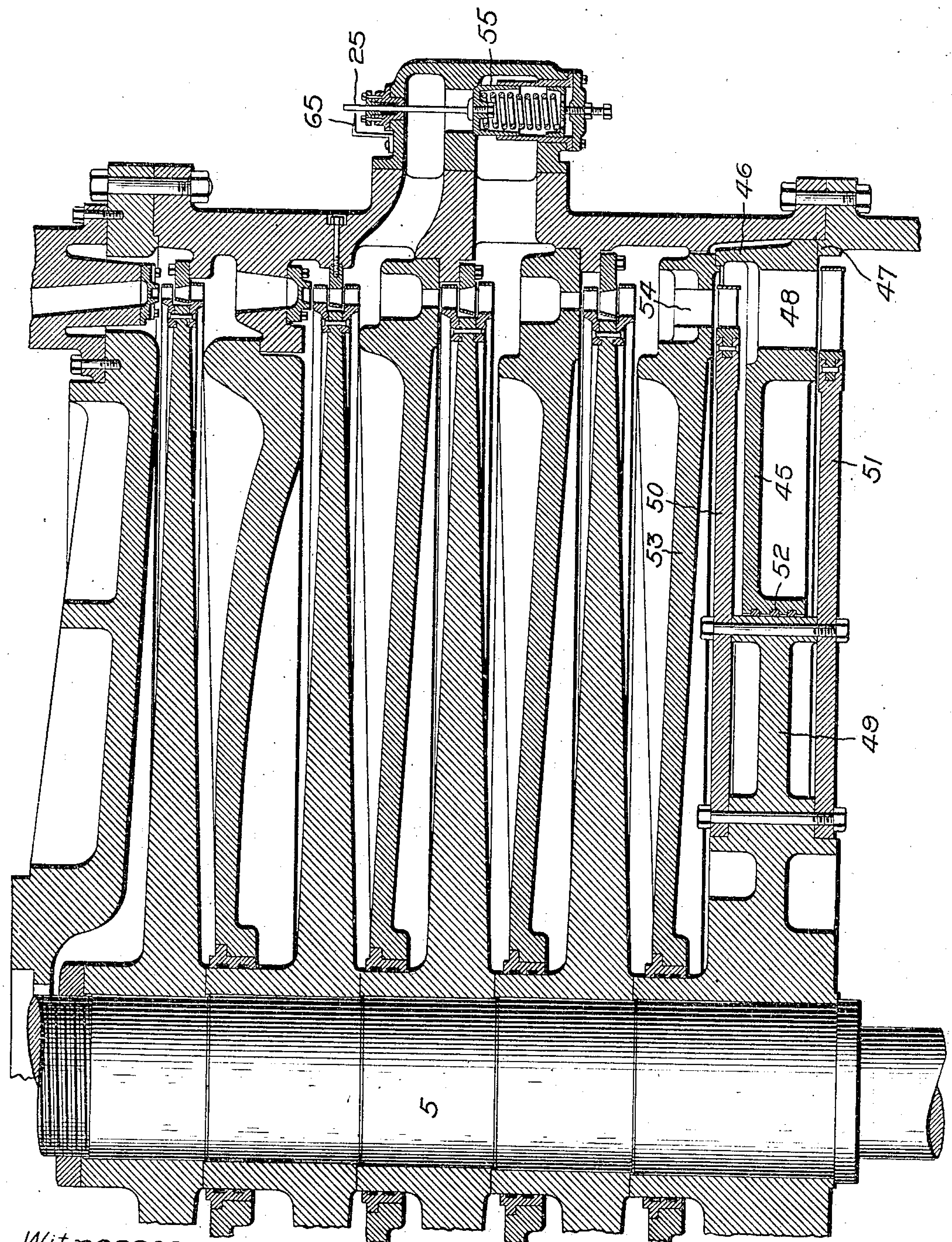

Fig. 5.

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6 SHEETS—SHEET 5.

Fig. 6.

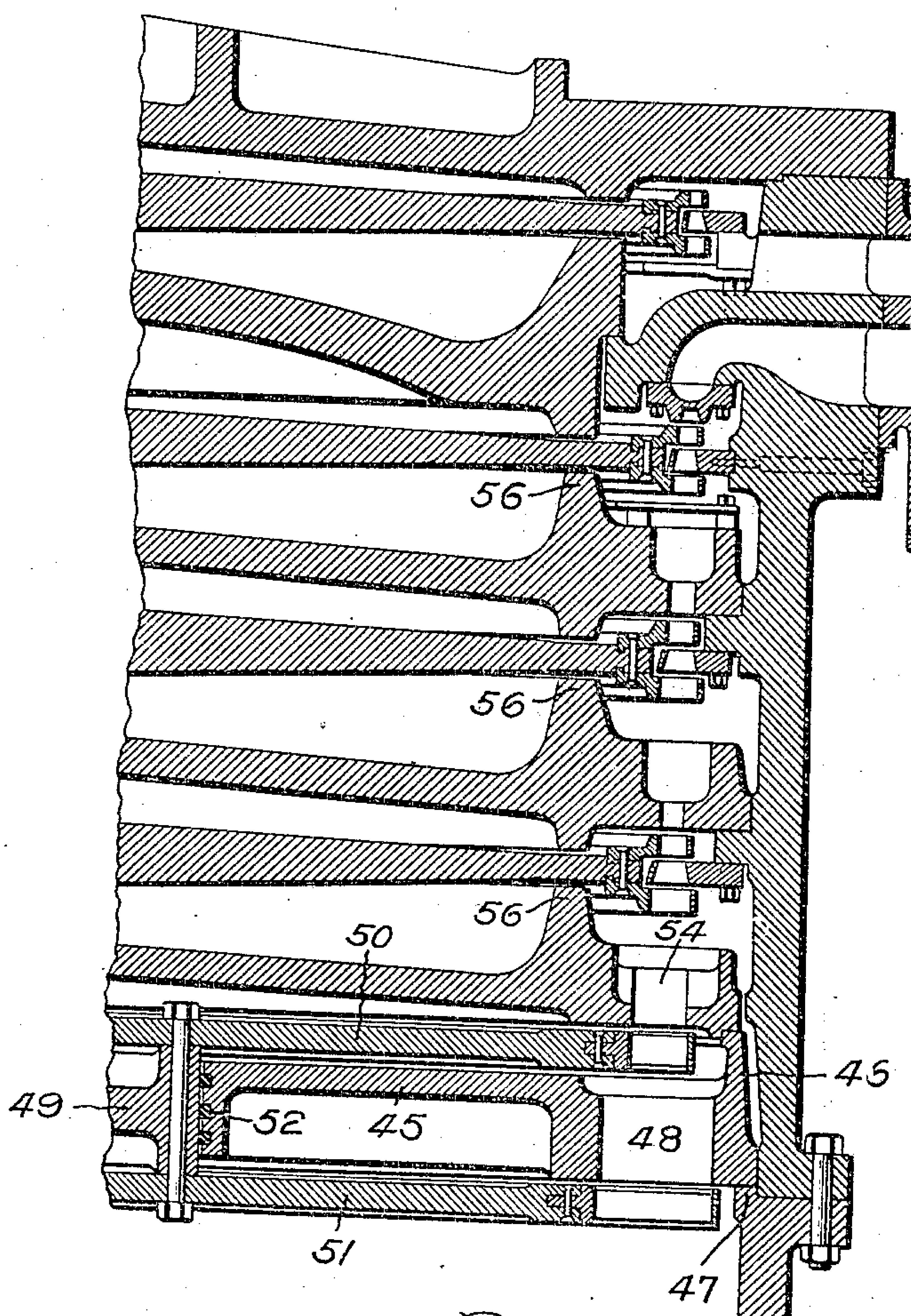


Fig. 9.

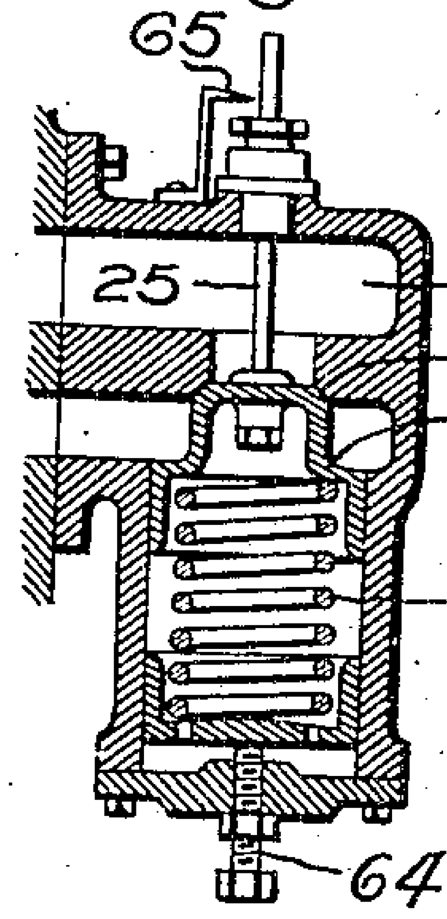
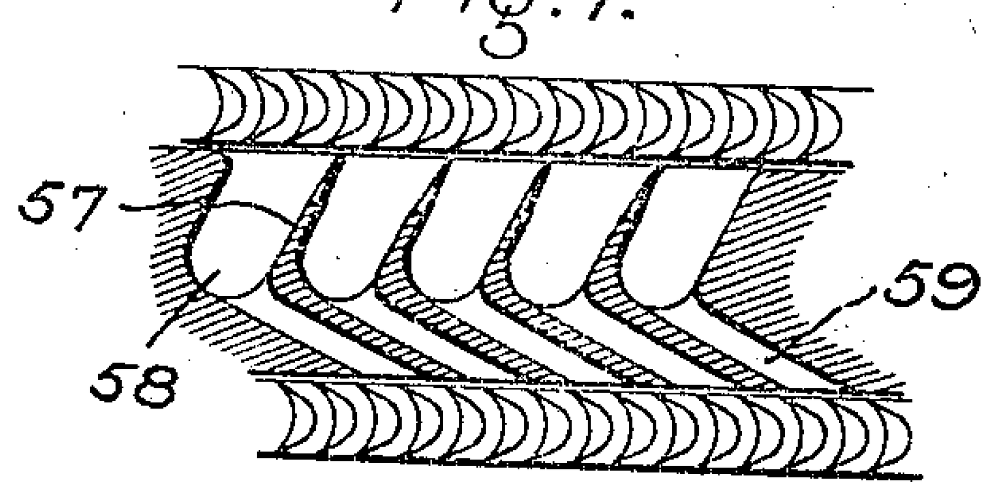


Fig. 7.



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6 SHEETS—SHEET 6.

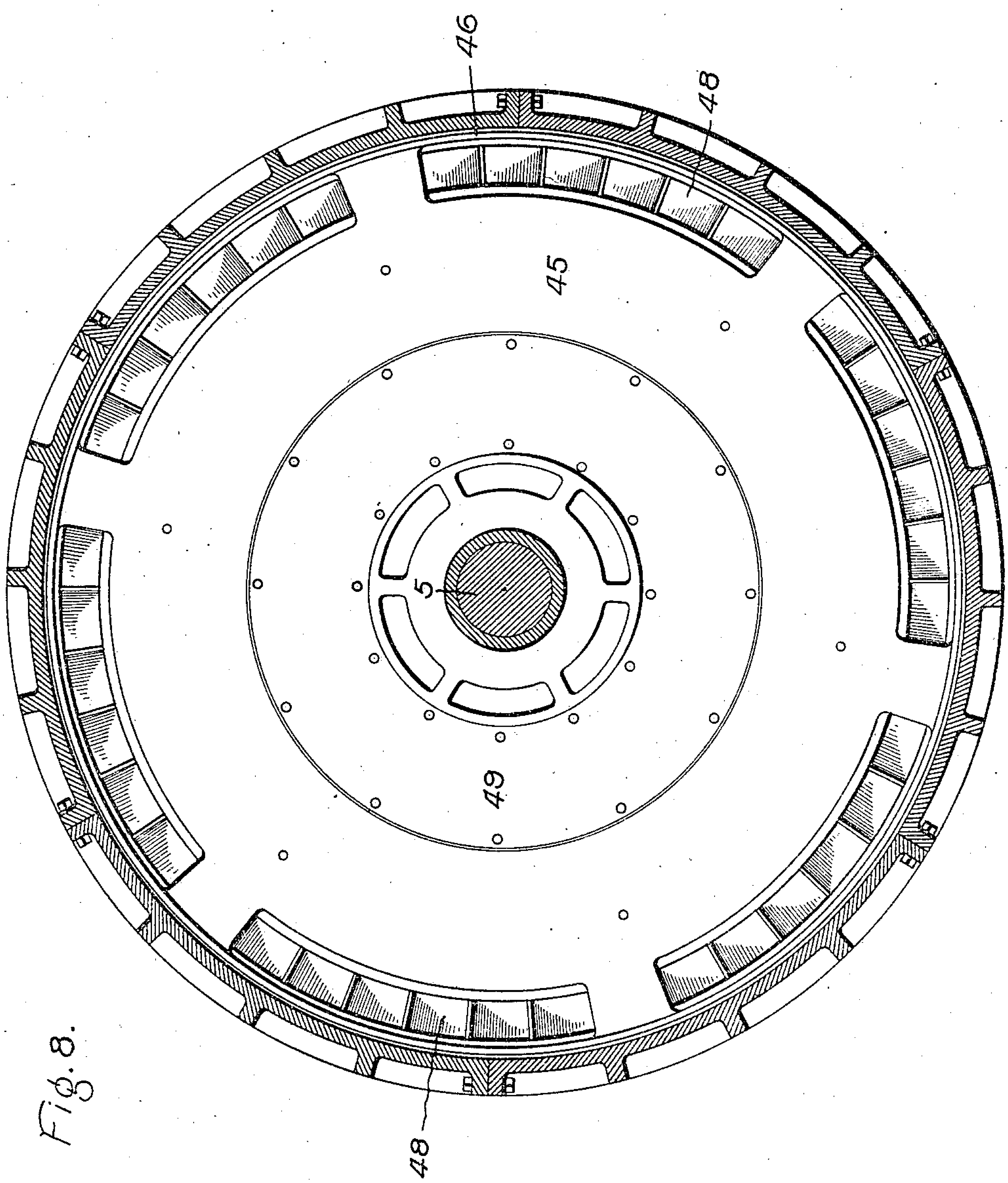

Fig. 8.

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UNITED STATES PATENT OFFICE.

OSCAR JUNGGREN, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ELASTIC-FLUID TURBINE.

No. 830,900. Specification of Letters Patent. Patented Sept. 11, 1906.

Application filed February 25, 1905. Serial No. 247,327

To all whom it may concern:

Be it known that I, OSCAR JUNGGREN, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Elastic-Fluid Turbines, of which the following is a specification.

The present invention relates to elastic-fluid turbines, and has for its object to improve their efficiency and also to simplify and improve their construction.

In carrying out my invention the turbine is divided into a plurality of stages, the number varying somewhat with changes in the operating conditions. Each stage is provided with a bucket-wheel and nozzles or nozzle-sections of the proper form to discharge steam or other elastic fluid against the bucket-wheel.

In the high-pressure stages the density of the fluid medium surrounding the bucket-wheels is greater than that of the lower stages. Hence the losses due to the fan-like action of the buckets and other parts and the surface friction between the parts and the surrounding fluid is greater in the former instance than in the latter. In order to reduce these losses as much as possible in the earlier stages, the wheels are made as small in diameter as is consistent with the power to be developed thereby, while the wheels of the later stages working in a vacuum more or less great are made considerably larger in diameter. The wheels are mounted on the same shaft, and therefore the bucket speed of the wheels of the high-pressure stages is less than that of the wheels of the low-pressure stages. Theoretically the buckets in this type of turbine should travel at half the speed of the fluid-stream; but since this would mean excessive rotation losses in the earlier stages due to high bucket speeds it becomes impracticable and in some cases prohibitive. In order to compensate for the reduced bucket speed, the wheels of each stage are provided with two or more rows of buckets, each row taking its share of energy from the motive fluid, and in this manner each stage will do its share of the work. Between the rows of wheel-buckets are intermediate buckets for conveying fluid exhausting from one row to the next. In the later or low-pressure stages the speed of the bucket-wheel may be made considerably higher, owing to the existence of a vacuum or greatly-reduced pressure and density of the fluid. Hence a single row of buckets in each stage suffices to abstract the velocity from the fluid-stream due to the preceding nozzle. In these stages, as in the earlier ones, the motive fluid is renozzled between stages and the pressure converted into velocity before striking the buckets. The number of stages provided with a single row of wheel-buckets is governed principally by the desired efficiency of the machine and also by the bucket speed. Other things being equal, the higher the bucket speed the fewer will be the stages.

By properly proportioning the nozzles and buckets the stages in the turbine may be made to perform equal amounts of work, which I consider to be the preferred arrangement; but, if desired, the stages may be arranged to perform unequal amounts of work.

The high-pressure stages are formed by a casing and diaphragms which are seated on separate shoulders cast integral with the casing.

In order to permit the parts to be assembled and taken down, the casing is divided in axial planes into two, three, or more parts, each of which will expose the wheels by moving it outwardly in a radial direction after taking out the retaining-bolts. The low-pressure stages are formed by a casing and diaphragms which rest one upon the other, the last diaphragm resting upon or engaging with a shoulder cast integral with the casing. The portion of the casing for the low-pressure stages is preferably formed in a single piece, thereby dispensing with all joints, except where it is united to the other portion of the casing. In this manner the troubles due to leakage are obviated and the cost and amount of labor involved in building are materially reduced.

Each of the low-pressure diaphragms is provided with a circumferential flange which, so to speak, incloses the wheel and furnishes a seat for the adjacent diaphragm of higher pressure. In this way one shoulder suffices to support all of the low-pressure diaphragms, and the construction of the turbine as a whole is greatly simplified. The fluid-pressure on each diaphragm serves to firmly hold it in place without attaching-bolts. When used in a horizontal machine, means may be employed to prevent the diaphragms from leaving their seats when the pressure is removed.

In assembling the low-pressure portion of the turbine the lower part of the casing is mounted on the foundation, then the shaft is mounted in place, then a wheel is mounted on the shaft, then a diaphragm is mounted in place, then a wheel, and so on. In taking down the machine the reverse order is followed. The active portion of the wheels and the area covered by the nozzles in the entire machine gradually increases from the admission to the exhaust.

Motive fluid is preferably admitted to the turbine by a plurality of independent and successively-actuated valves which are under the control of a speed-responsive device. The valves may be controlled electromagnetically by fluid-pressure or mechanically, as desired. The valve may be operated directly or through a relay mechanism. I may also use other principles of governing.

Between two, three, or more of the stages stage-valves are employed which respond automatically to pressure changes, and by controlling the passage of fluid through nozzles or other fluid-discharging devices tend to maintain the pressure in the stages constant. One, two, three, or more valves may be employed for each stage. Where two or more valves are employed, they preferably operate successively to admit fluid to a succeeding stage upon increase in pressure and cut off the supply upon a fall in pressure. This successive actuation of the valves both on increasing and decreasing loads may be attained by any suitable means—such, for example, as by changing the initial compressions of their opposing springs. Between some or all of the stages I may provide one or more valves which by-pass motive fluid from one stage to another without its doing useful work. These valves may be used with or without the stage-valves and respond automatically to pressure changes. It or they control one or more passages leading from one stage to another, either to an adjacent one or to those more remote. The valves preferably operate successively. This successive actuation of the valves may be attained by any suitable means—such, for example, as by weighting them differently by giving different initial compressions to their opposing springs.

It is customary to arrange the admission-valves in groups and to locate the groups equidistant about the turbine-casing. This arrangement while satisfactory where magnets with their flexible wires are employed to operate the valves is unsatisfactory where the valves are positively operated by mechanical means, because of undue complication and excessive number of parts. To obviate this difficulty, I arrange the nozzles in groups or sets about the wheels and space them equidistant or otherwise as before and form in the head or diaphragms of the machine, or both, fluid-carrying passages extending from the nozzles toward a common point. These passages are connected at said point to one or more steam-chests. Where separate chests are provided, they are preferably located in the same plane and as close together as possible. Each passage is under the control of a valve, and the latter is controlled by a speed-responsive device. By coring the passages or conduits in the head the machine-work is simplified and the losses due to radiation and condensation are small. Where it is desired to govern other stages after the first, the same arrangement can be followed wholly or in part, depending upon the conditions of operation, active area of wheels, &c.

The volume of steam or other elastic fluid passing through the low-pressure stages of a turbine is very large compared to that in the high-pressure stage. It is of course dependent upon the volume originally supplied and the difference in terminal pressure. Owing to the very large volume of fluid at low pressure and density, difficulty is experienced in properly directing it through the buckets. If the stationary or intermediate buckets are comparatively widely spaced, the steam may be and frequently is discharged at an improper angle, resulting in objectionable eddies and a loss in efficiency. Where the wheel-buckets are too widely spaced, some of the fluid-pressure passes through the spaces without doing useful work. On the other hand, if the buckets are placed close together, so as to get a better directive effect, the total cross-sectional area of the bucket-spaces will be too small and cause choking unless the wheel or intermediate support is very large in diameter. In order, therefore, to obviate the losses specified and at the same time obtain the full effect of the motive fluid, I provide a special construction for the low-pressure stages or stage. The high-pressure stages may be made in any suitable manner. I have found that two wheels per stage form a satisfactory construction. Some or all of the low-pressure stages have wheels provided with a single row of buckets, and situated between two adjacent wheels is what I term a "half-diaphragm." This diaphragm, instead of extending from the casing to the hub of the wheel, as usual, extends only about half of this distance. The adjacent wheels are bolted or otherwise secured to a common support, which is provided with a smooth peripheral surface coöperating with the inner surface of the half-diaphragm. The surfaces of the support and diaphragm are made relatively long in the direction of the shaft to reduce leakage. Special packing can also be employed, if desired. This construction has the further advantage of providing a stiff construction which is not liable to be distorted due to any cause. I may use this arrangement in one or more of the stages of higher pressure, if desired. If the support for the low-pressure wheels, which is carried by the main shaft, extended to a point close to the buckets, the pressure difference between the upper side of one wheel and the under side of the other (assuming, for example, that the invention is applied to a vertical-shaft machine) would be prohibitive in the case of large machines. By using a half-diaphragm and a support for the wheel-disks that extends only part way from the shaft to the buckets the pressure difference is reduced to a point where it can readily be taken care of, even in machines of large capacity having wheels of considerable diameter.

In the half-diaphragm are nozzles or fluid-discharging devices, which are made considerably longer than the intermediates, and nozzles of higher pressure to properly direct the fluid particles against the wheel-buckets and preserve the continuity of the fluid column. In fact, with this construction I am able to make the nozzle as long as is desired. The half-diaphragm is supported by a circumferential shoulder on the inside of the casing and in turn supports certain of the diaphragms above it. Some or all of the diaphragms are preferably provided with circumferential walls or projections which engage the wheel and prevent the buckets from being injured, due to shifting of the wheel or distortion from any cause. The clearance between the finished-edge surface of the wall and the wheel should be less than the clearance between buckets. When the wall or projection is continuous and forms a ring, it may assist in keeping the steam exhausting from the buckets out of the space around the shaft and hub, and thereby preventing or reducing the losses due to cross-currents. The steam leaving the buckets has a certain amount of residual velocity which acts after the fashion of an injector and tends to keep steam out of the central portion of the wheel-chamber.

In order to prevent the steam or other motive fluid exhausting from the buckets from striking the wall or walls of the casing and rebounding and opposing the rotation of the wheel or wheels, partitions between the bowls of the nozzle-sections are provided, which extend into close proximity with the wheel-buckets, and preferably at a point or points as nearly as possible in line with the preceding nozzle or nozzles.

In the accompanying drawings, showing certain embodiments of my invention, Figure 1 is an axial section of a vertical turbine. Fig. 2 is a plan view of a head or diaphragm, showing the arrangement of the passages for conveying fluid from the admission or controlling valves to the fluid-discharging devices. Fig. 3 is a detail sectional view showing the passages or conduits in the head or diaphragm. Fig. 4 is a transverse section of the turbine, showing a modified arrangement of the stage-pressure-controlling valves. Fig. 5 is an axial section of a turbine, showing a modified form of diaphragm. Fig. 6 is a similar view showing means for confining the motive fluid to its normal path and preventing cross-currents or eddies. Fig. 7 is a detail view showing means for preventing the fluid from rebounding and striking the wheel. Fig. 8 is a transverse section of the turbine shown in Fig. 5, the section being taken just above the low-pressure diaphragm. Fig. 9 is a detail view of a modified construction of the stage or by-pass valves, and Fig. 10 is a detail view showing a plurality of valves located in the same casing.

1 represents the base of the machine, which is made in a single casting and is supported by a suitable foundation 2. Steam or other elastic fluid is exhausted from the casing by a conduit 3. The central portion of the base is arranged to receive the detachable step-bearing 4, lubricating fluid being supplied thereto in any suitable manner. Rising vertically above the step-bearing is the main shaft 5, upon which are mounted wheels 6, each carrying buckets. The radial depth of these buckets increases somewhat from the high to the low pressure wheels. The buckets for the low-pressure wheels are provided with a base-piece 7, which is T-shaped in cross-section, and the projecting portion enters a peripheral groove or opening in the wheel and is retained in place by a bolt or rivet. The interior of the base portion of the casing is provided with a circumferential shoulder 8, upon which the lowest diaphragm 9 rests. This diaphragm is provided with a circumferential flange 10, which, so to speak, incloses the wheel and forms a part of the wheel-chamber. In other words, the diaphragm forms one side and the surrounding wall a wheel-chamber, the other side being formed by the diaphragm located above it. All the diaphragms in the low-pressure stages, with the exception of the one at the top, are similar in construction, and each diaphragm rests upon the flange of the adjacent lower-pressure diaphragm. These diaphragms are normally held in place by their own weight, and when the machine is in operation they are held in the position shown by the fluid-pressure thereon.

The upper portion of the wheel-case is made in the form of a cylinder and is divided into two or more pieces, the joints between the pieces being in axial planes. The upper surface of the lower half of the casing is finished to receive the lower surface of the upper half of the casing. Between the two parts of the casing is a shoulder 11 to assist in alining and securing the parts. Mounted on top of the upper portion of the casing is a head 12, which forms one wall of the upper stage and supports the valve-chest 13. The center of the head is bored out to receive the main shaft and carries a carbon packing-ring 14, which closely surrounds the sleeve of the shaft and is continually urged upward by the springs 15 and by any steam which leaks into the packing-chamber. Suitable packings are also provided between each of the diaphragms and the hub of the wheel. The upper portion of the casing is provided with a circumferential shoulder 16, that projects underneath one of the wheels and overhangs another. This shoulder forms a support for the uppermost diaphragm and in addition is provided with a number of passages 17, as shown on the left-hand side of Fig. 1, which passages supply steam or other elastic fluid to the nozzle 18. The number of these passages and the number of nozzles can be increased or decreased at will.

Situated between the wheel-buckets are intermediate buckets 19, which are secured in place by the same bolts that hold the nozzle 18 in position. By reason of this construction a single set of bolts suffices for both purposes. Upon the upper side of the shoulder 16 is a finished projection for carrying one or more sets of intermediate buckets 20, the latter being situated between the rows of buckets on the first wheel. The casing is also provided with another internal shoulder 21, which supports a diaphragm 22, the latter being somewhat larger in diameter than the one previously referred to. In this instance the nozzle is let into a circumferential groove on the low-pressure side and is secured in place by bolts. To the under side of the shoulder 21 is bolted one or more sets of intermediate buckets.

In order to maintain the pressure in the several stages substantially constant, one, two or more stage-valves 23 are provided which control the passage of fluid from one stage to the next. In the present instance two of these valves are shown between the first and second stages, which valves are designed and arranged to operate successively. In order to obtain this successive operation, the weights on the valves, as represented by the compression on the springs 24, are suitably arranged—that is to say, the compression on one spring is greater than that on the other. It will be noted that when the valve leaves its seat the area exposed to the steam is considerably increased, which causes the valve to open fully. The under side of the valve is exposed to the steam-pressure in the second stage, so that the spring only takes care of the difference in pressure between the two stages. For convenience the valve-casing is bolted to the outside of the wheel-casing, but obviously the valve may be located within the casing, if desired. In order that the position of the valve may be ascertained at any time, a stem 25 is provided which is attached to the valve and extends through the valve-casing and a suitable packing. Steam or other elastic fluid is admitted to the valve-casing by the passage 26, and after the valve is opened steam or other elastic fluid flows therefrom through the passage 27 to the adjacent nozzles. When the valve is closed, the nozzle or nozzles controlled thereby are cut off from the source of supply. This holds true irrespective of the number of valves employed, and it may here be stated that the number may be raised to suit the requirements.

In Fig. 2 the position of the valves will readily be seen. It is to be noted in connection with each one of these valves that the fluid it controls is employed to perform useful work in passing from one stage to the next. In the lower-pressure stages, however, valves are employed which are similar in their mechanical construction, but are so arranged that they by-pass a certain amount of steam or other elastic fluid from one stage into the next without its performing useful work. Such a valve is indicated at 28, of which one, two, or more can be employed. These valves should be adjusted by means of an adjusting-bolt or otherwise, so as to operate successively upon pressure changes in order to obtain a substantially constant pressure in the stages. Each of the valves is suitably weighted—as, for example, by a compression-spring—the stress of which can be changed at will. Each valve is also provided with an indicator 25, which extends through the casing and indicates whether it is open or closed. In Fig. 2 two successively-operating stage-valves and two successively-operating by-pass valves are employed which are spaced equidistant around the casing; but the arrangement can be changed, if desired.

Steam or other elastic fluid is admitted to the turbine by the conduit 29, which is in communication with the valve-chest 13. Located within the chest is a plurality of independent and successively-operating nozzle-valves 30. Each one of these valves may control one, two, or more nozzles or nozzle-sections or fluid-discharging devices. The valves may be operated directly or indirectly.

In Fig. 2 I have shown the preferred arrangement for the nozzles and controlling-valves. In this figure the nozzles, nozzle-sections, or other fluid-discharging devices are divided into groups and located on opposite sides of the main shaft. In the present instance two of these nozzle-sections are arranged to receive steam from the same conduit or passage; but the number can be increased or decreased, as desired. Extending from each pair of nozzles toward a common point is a conduit or passage 31, which is formed in the head or in the diaphragm where the valve arrangement is employed between the successive stages of a multistage machine. Each of these passages, of which as many may be employed as desired, terminates in a vertically-extending opening 32, which registers with a similar opening in the valve-chest 13, above referred to. With this construction the opening and closing of the valves 30 by any suitable means controls the flow of steam to the nozzles indicated at 33. From this it will be seen that all of the steam for the turbine is distributed from a single point. In the drawings the nozzles are shown as being divided into two groups; but obviously the number of groups may be increased, if desired.

Referring to Fig. 3, it will be noted that the passages in cross-section are relatively narrow as compared to their height. By reason of this construction a great many passages can be provided without taking up a great deal of room.

In Fig. 4 is shown a modified arrangement of the stage and by-pass valves. The valves are arranged in pairs in casings 35, that are bolted to the wheel-casing. Each casing is divided by a partition 36 into two parts or chambers, each containing a valve. The partition registers with a partition 37 in the wheel-casing, and at the sides thereof are passages 38 and 39, each of which communicates with a separate set of nozzles or nozzle-sections 40. The bowls of the nozzles are shown by dotted lines, and three nozzles receive fluid from the passage 38 and three from the passage 39. The valves controlling these passages open and close in succession. Situated diametrically across the machine are other and similar valves, which are also arranged to operate successively. In all, four of these stage-valves are shown for a given stage. One or more of the subsequent stages may be provided with similar valves arranged in pairs and inclosed in casings 41. These valves may act to control the stage-pressure by regulating the passage of fluid through the nozzles, or they may control the stage-pressures by by-passing the motive fluid from one stage to another.

In Fig. 10 is shown a casing 42, containing three valves 43, which are separated one from the other by partitions 44. Each of these valves controls the passage of fluid through a set of stage-nozzles. The valves are provided with suitable adjusting devices and springs, so that they may be set for simultaneous or successive operation. The casing is bolted or otherwise secured to the wheel-casing. Instead of controlling the passage of fluid through stage-nozzles these valves may act to by-pass motive fluid, as previously described.

In Fig. 5 is shown a slightly-modified construction of the turbine wherein the passage of fluid from one stage to the other is more effectively directed. The low-pressure wheels are separated by what I term a "half-diaphragm" 45. It is made in the form of a ring and is provided with a peripheral flange 46 for supporting the adjacent diaphragm of higher pressure. The half-diaphragm engages with and is supported by a shoulder 47, formed on the base portion of the wheel-casing. Only one of these diaphragms is shown; but the number can be increased, if desired. In the diaphragm are expanding or non-expanding nozzles or nozzle-sections 48, which are comparatively long in an axial direction for the purpose of effectively directing the passage of fluid to the adjacent wheel-buckets. The inner wall of the diaphragm is bored out to receive the support 49, which is common to the wheel-disks 50 and 51. Between the cylindrical wall of the diaphragm and the wheel-support packing-rings 52 may be provided to reduce the leakage. The wheel-disks and support are united by axially-extending bolts or equivalent devices. Mounted on the flange of the low-pressure diaphragm is a full diaphragm 53, which is provided with nozzle-sections 54, which are relatively long in an axial direction to effectively direct the motive fluid against the adjacent buckets.

Bolted or otherwise secured to the wheel-casing is one or more valves 55, which by-pass motive fluid around the diaphragm and nozzles between the second and third stages. This valve or valves is or are of the construction previously described.

The machines illustrated are of the vertical type; but my invention is applicable to those of the horizontal type. Some of the features of my invention are broad enough to include either an impulse or reaction machine or modification thereof, and the claims are to be interpreted with this in view.

In Fig. 6 the diaphragms between stages are provided with cylindrical walls or projections 56, which have a twofold purpose. They extend into close proximity to the webs of the wheels and prevent the motive fluid exhausting from the buckets from flowing at right angles to the shaft. In other words, these ribs prevent cross-currents of motive fluid in the wheel-chambers, which cause losses in efficiency and at the same time assist in directing and confining the motive fluid to its proper channels. The clearance between the projections and the wheel-webs is made less than that between the relatively movable buckets, so that any rubbing will take place at this point rather than between the buckets themselves or between the buckets and nozzles. This rubbing may be caused by unequal expansion of the parts or by distortion. It will be seen that any rubbing which does take place is on these large and rugged ribs, which being located near the periphery of the diaphragms are prevented from yielding by reason of the shoulders on the casing.

In Fig. 7 is shown a means for preventing or largely reducing the rebounding effect of the fluid exhausting from the buckets. When the fluid exhausting from a wheel with its residual velocity strikes a surface adjacent to the wheel, it is deflected and rebounds against the wheel web or buckets, or both, in a direction opposite to that of the moving wheel. This offers at times considerable opposition to rotation and means a loss in efficiency. To obviate this, partitions 57 are provided between the bowls 58 of the nozzles or nozzle-sections 59, which are preferably sharpened at their receiving ends and receive the fluid from the buckets and direct it into the bowls without giving it an opportunity to be deflected against the buckets in a direction contrary to their movement. The partitions may be set in a variety of ways; but preferably they should be at about the same angle as the discharged fluid.

In order to obviate the use of an especially long spring, on the one hand, or throttling action of the valve, on the other, the stage and by-pass valves are preferably constructed as shown in Fig. 9. The body 60 of the valve is provided with two portions of different diameters. When the valve is closed, the portion having the smaller diameter is exposed to the stage-pressure in the conduit 61; but just as soon as the valve opens the portion of larger diameter is exposed to the same pressure. By reason of the increased area exposed to the fluid-pressure the valve will be opened fully and held in this position until the pressure conditions in the stage or stages are decreased by a certain predetermined amount, when the valve will definitely close. By making the diameter of the lower portion of the valve relatively large with respect to the valve-opening the action of the valve can be controlled within the narrow limits. The end of the valve is slightly beveled, as is also the seat 62. The valve is normally pressed against its seat by the spring 63, and the stress exerted by the latter can be changed at will by the adjusting-bolt and nut 64. This valve, as well as the others, is provided with an indicator 25 and a pointer 65, which is affixed to the casing of the machine or other fixed part.

In accordance with the provisions of the patent statutes I have described the principle of operation of my invention, together with the apparatus which I now believe to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In an elastic-fluid turbine, the combination of a casing divided into stages, wheels in the high-pressure stage each having rows of buckets for fractionally abstracting the velocity of the motive fluid, wheels in the low-pressure stages each having a single row of buckets, the buckets in the low-pressure stages having a greater speed than those in the high-pressure stages, and means discharging motive fluid against the wheel-buckets of the stages.

2. In an elastic-fluid turbine, the combination of a casing, diaphragms for dividing the casing into wheel compartments or stages, the diaphragms of the low-pressure stages having a greater diameter than those of the high-pressure stages, wheels in the high-pressure stages, each having rows of buckets for fractionally abstracting the velocity of the motive fluid, wheels in the low-pressure stages, each having a single row of buckets, the low-pressure wheels being of greater diameter than the high-pressure wheels and having greater bucket speed than the high-pressure wheels, and nozzles for converting the pressure of motive fluid into velocity and discharging it against the wheel-buckets.

3. In an elastic-fluid turbine, the combination of a casing, diaphragms for dividing the casing into compartments, a separate support for each of the high-pressure diaphragms, and a support which is common to all of the low-pressure diaphragms.

4. In an elastic-fluid turbine, the combination of a casing, diaphragms for dividing the casing into compartments, a separate shoulder formed in the casing for each of the high-pressure diaphragms, and a shoulder formed on the casing, which is common to all of the low-pressure diaphragms.

5. In an elastic-fluid turbine, the combination of a casing, diaphragms for dividing the casing into compartments, the high-pressure diaphragms increasing in diameter toward the exhaust, the low-pressure diaphragms being of the same diameter and larger than the high-pressure diaphragms, a separate support for each of the high-pressure diaphragms, and a support common to all of the low-pressure diaphragms.

6. In an elastic-fluid turbine, the combination of a casing, diaphragms for dividing the casing into compartments, the low-pressure diaphragms being provided with flanges which engage and support the adjacent low-pressure diaphragms, separate shoulders formed on the casing for supporting the high-pressure diaphragms, and a shoulder formed on the casing which is common to all the low-pressure diaphragms.

7. In an elastic-fluid turbine, the combination of a casing comprising a portion made in

a single piece, a second portion made in separate pieces divided in an axial plane and attached to the first, high and low pressure diaphragms, a shoulder formed on the first portion which forms a support common to the low-pressure diaphragms, and shoulders for the high-pressure diaphragms.

8. In an elastic-fluid turbine, the combination of a casing, a shoulder formed thereon, a diaphragm supported by the shoulder, bucket-wheels, intermediate buckets attached to one side of the shoulder, and nozzles intermediate to the other.

9. In an elastic-fluid turbine, the combination of a casing having an internal shoulder, bucket-wheels mounted in the casing, and intermediate buckets located between the rows of wheel-buckets, which are supported by the shoulder on the opposite side from the diaphragm.

10. In an elastic-fluid turbine, the combination of a casing, a shoulder formed thereon, a diaphragm supported by the shoulder, bucket-wheels, a nozzle, intermediate buckets, and a means common to the nozzle and buckets for securing them to the shoulder.

11. In an elastic-fluid turbine, the combination of a casing, a shoulder formed thereon, a diaphragm engaging the shoulder, a nozzle carried by the shoulder, a passage extending through the shoulder and supplying the nozzle with motive fluid, and a valve responsive to pressure changes for governing the flow of fluid through the passage to the nozzle.

12. In an elastic-fluid turbine, the combination of a plurality of stages, bucket-wheels therefor, nozzles or devices discharging fluid against the bucket-wheels, and one or more valves which receive fluid from one stage and by-pass it around a fluid-discharging nozzle or device without its doing useful work in passing.

13. In an elastic-fluid turbine, the combination of a plurality of stages, bucket-wheels therefor, nozzles or devices discharging fluid against the bucket-wheels, one or more valves which receive fluid from one stage and by-pass it around a fluid-discharging nozzle or device, and one or more valves which receive motive fluid from one stage and discharge it through a nozzle or device into another stage.

14. An elastic-fluid turbine of the multistage type, comprising revolving buckets and fluid-discharging devices, in combination with valves which are responsive to pressure variations for regulating the passage of fluid through said fluid-discharging devices from one stage to another, and other valves also responsive to pressure variations for by-passing fluid around the fluid-discharging devices.

15. An elastic-fluid turbine of the multistage type, comprising revolving buckets and fluid-discharging devices, in combination with a plurality of successively-acting valves which are responsive to pressure variations for regulating the passage of fluid through said fluid-discharging devices from one stage to another, and a plurality of successively-acting valves also responsive to pressure variations for by-passing fluid around the fluid-discharging devices.

16. An elastic-fluid turbine of the multistage type, comprising a casing, revolving buckets and fluid-discharging devices, in combination with valves located in a common casing, the said casing being supported by the turbine-casing.

17. An elastic-fluid turbine of the multistage type, comprising a casing, revolving buckets and fluid-discharging devices, in combination with successively-acting valves responding to pressure changes, which control the passage of fluid from one stage to another, and a casing common to the valves which is supported by the turbine-casing.

18. An elastic-fluid turbine of the multistage type, comprising a casing, revolving buckets and fluid-discharging devices, in combination with valves responding to pressure changes, which control the passage of fluid from one stage to another, a casing which is common to the valves, and a partition in the casing, which separates the valves one from the other.

19. An elastic-fluid turbine of the multistage type, comprising a casing, revolving buckets, devices admitting fluid to the turbine, nozzles between stages arranged in sets, in combination with pressure-responsive valves controlling the passage of fluid through said sets of nozzles, a divided casing which is common to the valves, one of said valves controlling the passage of fluid through one set of stage-nozzles, and another valve controlling the passage of fluid through another set of stage-nozzles.

20. In an elastic-fluid turbine, the combination of a bucket-wheel, a casing therefor, a head or diaphragm for the casing, which is provided with fluid-carrying passages extending toward a common point, and devices receiving fluid from the passages and discharging it against the buckets.

21. In an elastic-fluid turbine, the combination of wheel-buckets, a casing therefor, a head or diaphragm for the casing, fluid-discharging devices arranged in groups around the head or diaphragm, conduits extending toward a common point, and valves located at said point for controlling the admission of fluid to the conduits.

22. In an elastic-fluid turbine, the combination of wheel-buckets, a casing therefor, a head or diaphragm for the casing, fluid-discharging devices arranged in groups or sets

around the head or diaphragm, conduits extending from the fluid-discharging devices toward a common supply-point, each conduit supplying more than a single device, a chest for supplying fluid to the conduits, and valves controlling the passage of fluid from the chest to the conduits.

23. In a turbine, the combination of a casing having an internal shoulder, a flanged diaphragm supported thereby, a second diaphragm mounted on the flange of the first, and a means carried by the second diaphragm for preventing cross-currents of motive fluid in the wheel-compartment in which it is located.

24. In a turbine, the combination of a casing having an internal shoulder, a flanged diaphragm supported thereby, a second diaphragm mounted on the flange of the first, and a cylindrical wall carried by the second diaphragm for preventing cross-currents of motive fluid in the wheel-compartment in which it is located and also for preventing the buckets from rubbing.

25. In a turbine, the combination of a casing, bucket-wheels, nozzles for discharging fluid, a diaphragm located in and dividing the casing into compartments, the diaphragm having a peripheral flange, a second diaphragm mounted on the flange of the first and wholly within the casing, a cylindrical wall carried by the second diaphragm which prevents cross-currents of motive fluid in the compartment in which it is located and also serves to direct the passage of fluid through the adjacent nozzles.

26. In an elastic-fluid turbine, the combination of a casing which is divided into stages, bucket-wheels for the stages, a nozzle or device for discharging fluid to the wheels which is divided by walls into individual passages, and partitions forming continuations of the walls for receiving the fluid exhausting from the buckets before it enters the bowl and preventing it from rebounding against the wheel.

27. In an elastic-fluid turbine, the combination of a casing, partitions for dividing the casing into stages, bucket-wheels for the stages, admission-nozzles, bowls for the stage-nozzles, and partitions located between the bowls and extending in the same general direction as the fluid exhausting from the buckets and beyond the bowls for preventing the rebounding of exhaust fluid against the buckets and for directing the fluid into the nozzle-bowls.

28. An elastic-fluid turbine of the multistage type, in combination with a plurality of valves responsive to changes in stage-pressure for controlling the passage of fluid between stages, the said valves being provided with double areas.

29. An elastic-fluid turbine of the multistage type, in combination with a plurality of individual and successively-acting valves which open and close in response to pressure changes for controlling the passage of fluid through the turbine, each of said valves being provided with double areas and an opposing weight.

30. In an elastic-fluid turbine, the combination of a casing having an internal support, a diaphragm resting on the support, the said diaphragm being provided with a circumferential flange, and a second diaphragm mounted on the cylindrical flange of the first, the said diaphragms occupying their positions solely by reason of their weight and the fluid-pressure thereon.

31. In an elastic-fluid turbine, the combination of a casing having an internal support, a diaphragm mounted on the support and having a cylindrical and axially-extending flange, one or more similar diaphragms mounted on said flange one above the other, the said diaphragms occupying their positions solely by reason of their weight and the aggregate pressure of the motive-fluid on the diaphragms of the successive stages.

In witness whereof I have hereunto set my hand this 23d day of February, 1905.

OSCAR JUNGGREN.

Witnesses:
ALEX. F. MACDONALD,
HELEN ORFORD.